The SIRTF Telescope Test Facility: The First Year

Melora Larson, Mark Lysek, Daniel R. Coulter, and Steven A. Macenka

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Dr.
Pasadena, CA 91109-8099

ABSTRACT

The SIRTF Telescope Test Facility (STTF) consists of an optical dewar for testing mirrors of up to 1m diameter and f < 6 at temperatures from 300K to 5K and a phase shift interferon] eter for optical characterization. The STTF was brought on line in early 1995. The STTF was initially used to cool a 50cm diameter beryllium mirror that had been previously tested at NASA Ames Research Center. These initial tests validated the performance of the STTF by proving that the STTF could cool a mimer to SK and achieve high quality optical data on the mirror, consistent with the previous results achieved at NASA Ames. The STTF has also been used to provide cryogenic optical testing of therritra-lightweight 85cm diameter beryllium primary mirror assembly (PMA) for the Infrared Telescope Technology Testbed (ITTT). Currently the facility is preparing for testing the complete ITTT. Also, the long wavelength photon background in the facility will be measured and characterized in 1996.

Key words: Cryogenic optics, optic testing, SIRTF, i infrared

1. INTRODUC1'1ON

Because of the lessons learned from the Hubble Space Telescope, there has been an increased desire for end-to-end testing of optical systems designed for usc in space. To maximize the scientific return within the current strict budget, and therefore weight constraints, it is necessary to develop new, light-weight telescopes for satellites, The Integrated Telescope Technology Testbed (IITT) has been developed at JPL as an effort to build an rrltra-lightweight cryogenic infrared telescope for the Space Infrared Telescope Facility (SIRTF). During the initial design phase of the H-l-l', an effort was made to find a facility capable of performing the desired cold optical characterization of the ncw telescope. A thorough search of existing facilities found that none existed that could cool optics as large as needed for the 1'1'1'1' to SK and perform optical characterization. Therefore, in the spring of 1994, JPL decided to embark on building a cryogenic optical facility for testing mirrors of diameter ≤1m with f ≤ 6. The facility went from initial concept to a fabricated, assembled and tested facility in less than 12 months. The initial cool down and optical characterization of the facility was performed in April of 1995. Below, we will discuss both the capabilities of the facility and the improvements that have been made to the facility during its first year of operation.

2. FACILITY DESCRIPTION

The S'1'1'1; was designed to perform optical characterization at ambient, 77K and 4K temperatures. The STTF consists of a very large. optical dewar that mounts on an aluminum triangular vibration isolation frame supported by 3 pairs of Newport 1-2000 pneumatic isolators and a Zygo GPI phase shifting visible interferometer. The dewar portion of the STTF is constructed of a series of nesting shells (see figure 1). The outer shell provides the vacuum seal necessary for thermally isolating the inner shells of the facility. The outer shell also provides optical access to the test object and has feedthrus for manipulating the gimbal mount inside the facility[1] and a cryogenic optical shutter. The middle shell consists of a 300 liter liquid nitrogen tank topped with a removable aluminum radiation shroud that is conductively cooled . The inner shell consists of a bottom 300 liter liquid helium tank, an aluminum radiation shroud that mounts cm the bottom tank, and an upper 300 liter liquid helium

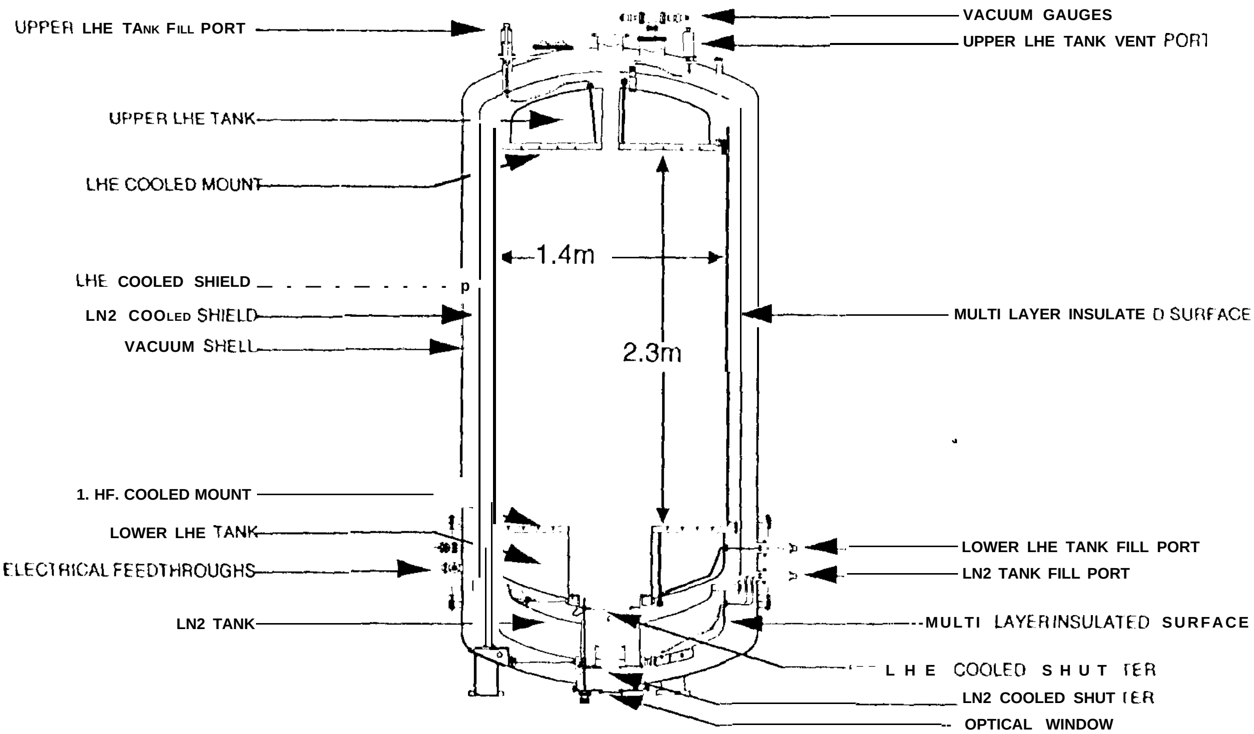

Figure 1: Schematic diagram of the STTF. The inner helium cooled space contains 2 mounting surfaces

tank that mounts inside the helium radiation shroud. Considerable design effort was spent trading off between initial costs of the facility and thermal cycle cost of the facility while considering the case of assembly/use of the. finished facility. Further details on these aspects of the STTF can be found in Luchik et al[2].

To validate the thermal and optical performance of the STTF, a 50 cm diameter beryllium mirror was mounted in the facility during the initial cool down. This mirror had been previously characterized optically as a function of temperature in a smaller facility similar to the STTF at NASA Ames Research Center. The results from the initial testing were very good. The mirror was successfully cooled to SK, and all of the optical results were. consistent with those seen previously with this mirror.

3. FACILITY IMPROVEMENTS:

From the initial cool down, there were two areas of the facility opc.ration/performance that showed room for improvement. The first was the cryogen consumption during cooling to 77K and the cooling time for the tanks from ambient to 77K. By installing a direct connection between the STTF and a large, outside house liquid nitrogen tank, all three tanks, the nitrogen and both of the helium tanks, were able to be filled with liquid nitrogen within 16 hours instead of the 28 hours need previously. Originally, the facility was filled from a set of five 1601 storage tanks that had to be refilled at least 3 times each as the facility was cooled from ambient to 77K.

The other aspect of the STTF that was targeted for improvement was the temperature profile in the helium radiation shroud

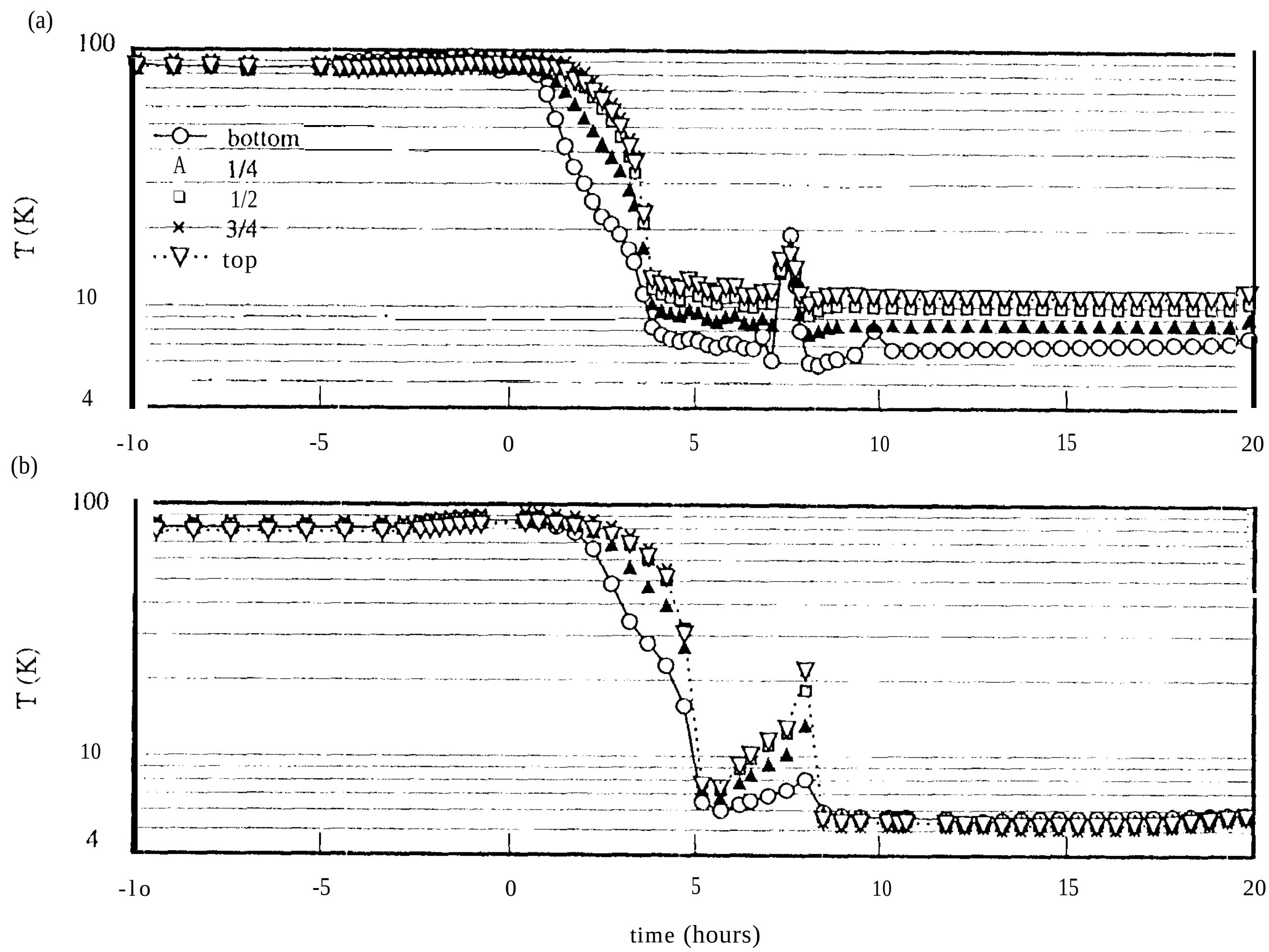

Figure 2: Temperature distribution along the length of the helium shroud as a function of time from the start of liquid helium transfer. (a) Original configuration with upper helium tank not strapped to shroud. (b) Improved configuration with copper straps between the upper helium tank and the top of the helium shroud.

when the helium tanks were full of liquid helium and in equilibrium at 4K. As can be seen from figure 2a, during the first cool down of the STTF to 4K, the steady state temperature of the shroud varied from slightly above 7K at the bottom to 11 K at the top. This variation in temperatures, and especially the 11 K maximum temperature of the shroud, caused concern that the final end to end tests of the telescope with integrated detectors could not be performed in the STTF due to large background thermal radiation from the warm portions of the shroud. From the temperature profile, it was clear that the shroud was not well thermally connected to the upper helium tank. So, twenty two thermal straps 0.6m long made from solid 32mm x 3mm OFHC copper were installed *between* the upper helium tank and the top of the helium shroud. As can be seen in figure 2b, installing these straps not only removed the thermal gradient in the. shroud, but it also lowered the average temperature of the shroud to about 5.5K, below the previous low temperature for the unstrapped shroud. The shroud temperatures with the straps installed meet the current requirements for the possible detector testing in the facility.

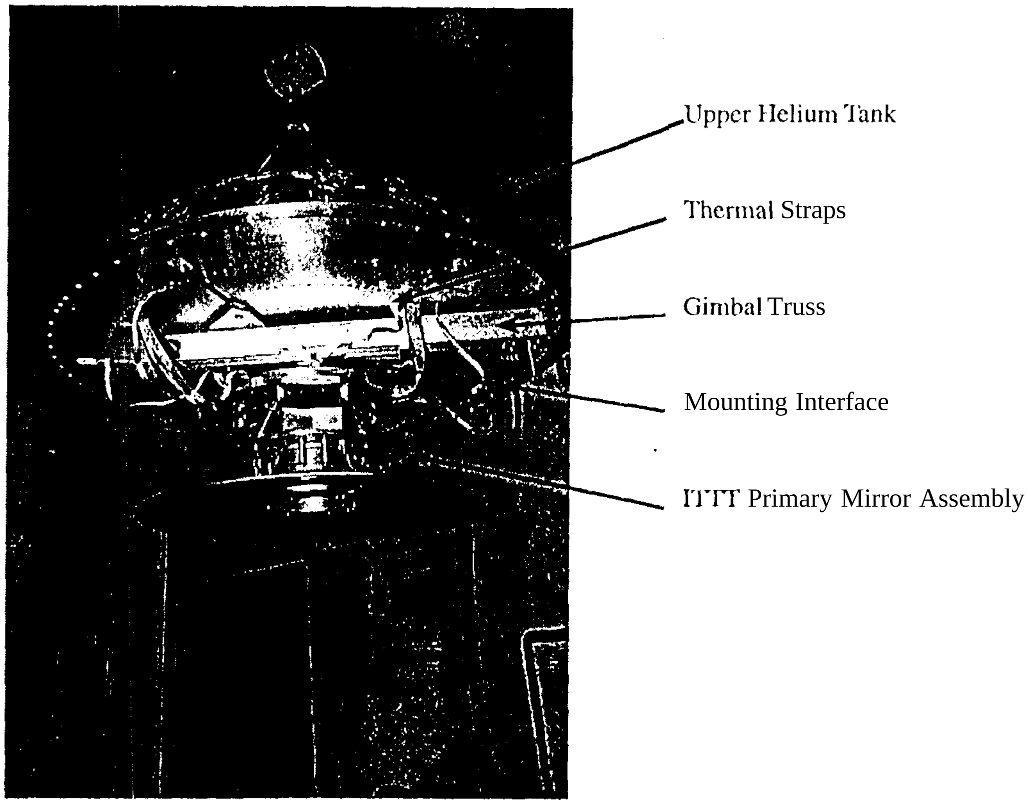

*Figure 3: The PMA installed on the upper **helium** tank. prior to the start of optical and thermal testing at JPL*

4. CRYOGENIC TESTING

3.1 lest cycle

A test in the STTF begins with the mounting of the test object, mirror or telescope, on one of the helium tanks. Since the optical mounts are not solid, thermal mounts between the object and the helium tank, copper braid is also installed between the test object and the helium tank to facilitate, cooling of the test object (see figure 3). Once the STTF is then reassembled with the test object inside, it is evacuated and baseline ambient interferograms are taken. 'l"he facility is pumped until a vacuum of 5 x 10-s Torr is achieved before proceeding with the cool down to 77K. A typical cool down including stabilizing at 77K, 4K and again at 77K is shown in figure 4 as a function of time . This cool down was prior to the installation of the outside, house liquid nitrogen tank discussed in section 3 above, so as can be seen from the plot, both helium tanks did not reach 77K until about 28 hours after the cool down started. In later tests, this time was reduced to 16 hours as stated above. Because of the particular size of strapping used between the ITTT Primary Mirror Assembly (PMA) and the helium tank in this example cool down, the mirror took over 6 days to reach equilibrium at 77K. This time will vary from test object to test object, set by the. thermal mass of the test object and how many thermal straps can be practically installed, 'lie cooling of the test object can also be increased by adding small amounts of nitrogen exchange gas in the overall vacuum space of the STTF. Once equilibrium at 77K is reached, any exchange gas is pumped out and a series of 77K interferograms are. taken. Any remaining liquid nitrogen in the helium tanks is then blown out and liquid helium is transferred into both helium tanks. The cool down between 77K and 4K is much more rapid than (hat between 300K and 77K. Equilibrium at 4K is reached within 15 hours of the start of the helium transfer. The STTF can sit at 4K for about 30 hours after equilibrium is reached without

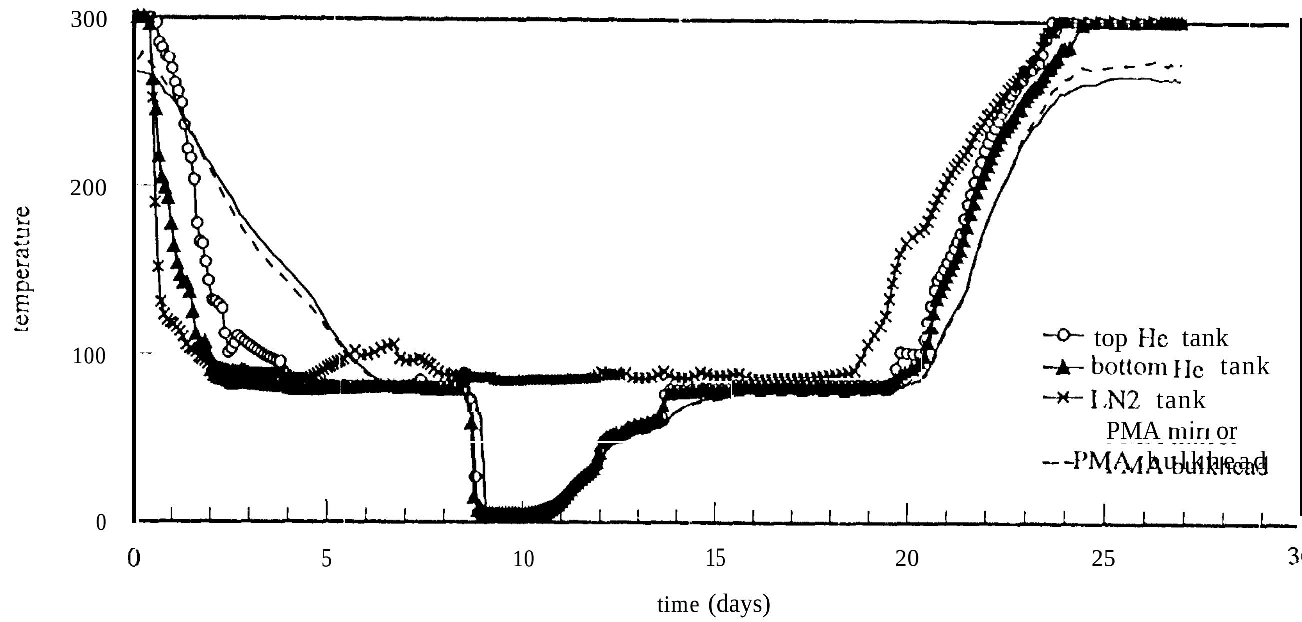

Figure 4: Cooling behavior as a function of time (O is midnight on the day cooling was commenced). Data was taken from the initial cooling cycle *of the PMA. As seen from the figure, the thermal coupling between the facility and the mirror sets the overall time scale for the tests.*

any additional fill of liquid helium. While at 4K, additional interferograms of the test object arc taken. For this particular test, after the helium tanks boiled dry, they were warmed with flowing helium gas to 65K and a small amount of liquid nitrogen was put into each liquid helium tank. Once the mirror reached 77K, another set of interferograms were taken, the liquid nitrogen in all 3 tanks was blown out ,and a fcw Torr of dry nitrogen gas was placed in the vacuum space to hasten the warm up to ambient,

The STTF has now been cycled between 300K and 77K five times, and it has been cycled an additional five times from 300K to 4K. An average test between 300K and 77K takes about 10 days. If a test to 4K dots not need to stabilize at 77K during the warm up, a 4K test cycle can be completed in about 2 weeks. It is also important to note that because of the strong vibration damping of the system, all of the optical data can be, and is taken with the system during normal working hours.

3.2 **Test results for the ITTT PMA**

The PMA for the ITTT was delivered to JPL from Hughes Danbury Optical Systems (111)0S) in late July 19953, Because historically large beryllium optics have shown "thermal hysteresis", changing their shape following cycling between cryogenic temperatures and room temperature, the PMA was cycled five times [o 77K after the initial cool clown to 4K, and then another 2 additional times to 4K for performing detailed figure analysis of the mirror as a function of temperature. During the 7 months that the mirror underwent these cycles, no noticeable hysteresis was detected in the room temperature profile of the mirror. There was noticed a significant cryo-distortion upon cooling the mirror from ambient to 77K. The distortion did not change appreciably when the mirror was cooled ful-(her, to 4K. The distortion was repeatable and did not change over this 7 month testing cycle even with variations in the mounting scheme for the mirror [3]. Because the distortion was repeatable, measurements of the shape of the mirror were made. during the final cooling cycle so that the mirror could be ground so that the figure of the mirror will not show any distortion when cold,

5. FUTURE PLANS

The ITTT PMA was returned to HDOS for refiguring at the close of the thermal cycling. The PMA should be returned to JPL in mid 1996, and it will be installed in the STTF for new thermal/optical characterization. Also, the remaining portions of the telescope for the ITTT will also arrive at JPL in 1996, and will be integrated with the PMA and tested in the STTF.

Parallel to the testing of the ITTT, there is an ongoing effort to redesign the inner helium interfaces (between the shroud and the 2 tanks) to cut down the optical path between the nitrogen shroud and the helium test region. Hopefully by the end of 1996 this will lead into a measurement of the optical background in the facility at wavelengths near 30μm. This measurement will be useful in fully characterizing the STTF and will also be used in planning of future integrated testing of a telescope and detectors.

6. ACKNOWLEDGEMENTS

The STTF was jointly funded by NASA Code X, the SIRTF Project out of the NASA Office of Space Science, and JPL institutional resources. Funding for the ITTT was provided by NASA through the Spacecraft Systems Division of the Office of Space Access and Technology (Code XS) as part of the Telescope I'ethnology Program.

7. REFERENCES

1. R. G. Chave, A. E. Nash, and J. Hardy, "Gimbal Mechanism for Cryogenic Alignment of 1 Meter Diameter Optics", SPIE Paper 2542-03, 1995.

2. '1'. S. Luchik, U. Israelsson, et. al, "SIRTF Telescope Test Facility", SPIE Paper 2553-49, 1995.

3. D. R. Coulter, S. A. Macenka, M. J. Lysek, and M. Larson, "The SIRTF Telescope Test Facility", SPIE Paper 2744--77, 1996.